Preventing Building-Related Symptom Complaints in Office Buildings

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ABSTRACT

Purpose. The goal of this project was to develop practical strategies for preventing building-related symptoms in office buildings, based on the experience of those who investigate buildings with health complaints, and suitable for use by those who own, lease, or manage office space.

Methodology/approach. Ideas from six experienced building investigators on primary causes and key prevention strategies were gathered and prioritized through consensus and voting in a structured, multi-day workshop.

Findings. IEQ investigators from diverse climatic regions agreed on the most important problems causing symptom complaints in office buildings, and the key strategies for prevention. The top ranked problems identified were, in priority order: excessive building moisture, inadequate outdoor air, excessive dust, pollutant gases and odors, inadequate thermal control, and inadequate attention by management to indoor environments. The highest priority recommended prevention strategies for building-related symptoms were: managing moisture at building exteriors, operating ventilation systems per design intent, providing at least the minimum recommended ventilation rates, and maintaining indoor temperatures at 72°F ±2° (22°C ±1°). Available scientific findings were generally consistent with these recommendations.

Research limitations/implications. Validity of these findings, from a subjective synthesis of empirical knowledge, not from scientific research, has not yet been scientifically confirmed.

Practical implications. These recommendations, including managing moisture at building exteriors, providing adequate ventilation, and controlling indoor thermal conditions, provide practical, empirically based guidelines for those who own, manage, or maintain office buildings.

Originality/value. The empirical knowledge of practitioners, concentrated and synthesized here, offers more direct guidance for health-protective strategies in office buildings than current science.

Key words: indoor environmental quality, sick building syndrome, symptoms, ventilation, moisture, office buildings

Introduction

Complaints by occupants in offices and commercial buildings of health symptoms, discomfort, and odors (sometimes called "sick building syndrome" or building-related symptoms) have been documented for almost 30 years. These problems have persisted despite decades of investigation and increasing scientific research. Occurrence of these building-related symptoms has been estimated to cause important reductions in performance among the occupants working in these buildings (Fisk, 2000; Mendell et al., 2002a).

Available scientific information is too limited to identify the specific indoor exposures (such as particular chemicals or microorganisms) that cause building-related symptoms in occupants of office buildings, much less to establish what levels of these exposures are safe. Thus, setting documented health-protective *indoor exposure standards* (that is, reference levels that should not be exceeded, and below which these adverse effects in building occupants would not occur) has not been possible in these buildings. Nor, in the absence of documented indoor exposure standards, has scientific research documented a set of *building-related practice standards* that have been shown to prevent occurrence of building-related symptoms (that is, ways of designing, operating, or maintaining buildings that prevent these health effects in occupants without measurement of specific contaminants).

In the absence of exposure or practice standards scientifically demonstrated to protect health, the most effective current strategies for preventing building-related symptoms rest on *empirically based* concepts of "good building practice" rooted in the experience of building professionals. This experience has provided input for some formal consensus guidelines, such as current ventilation standards.

For many aspects of indoor environmental quality (IEQ), however, no formal process exists for distilling professional experience into guidelines for protecting occupants. Although a variety of building professionals such as facility managers have experience of this kind, the most concentrated experience regarding successful and unsuccessful building practices and features exists among those professionals who investigate buildings with occupant health, comfort, and odor complaints. We will refer to these professionals as IEQ investigators.

The goals of the current project were to utilize the practical knowledge and experience of leading IEQ investigators to:

(a) Identify the most important environmental factors *leading to* IEQ problems and the resulting complaints of building-related symptoms, discomfort, and odors in office workers, and

(b) Develop a set of key recommendations for *preventing* these building-related problems and their adverse effects on health, comfort, and productivity, suitable for use by those who buy, lease, or manage office space.

The project brought together six experienced IEQ investigators with decades of combined problem-solving experience in thousands of buildings. A group process gathered and summarized their knowledge about the key environmental factors causing building-related symptoms in office buildings, and the key strategies for preventing these problems. The results

were compared to current scientific knowledge, and summarized for use in developing practical guidelines for maintaining good IEQ.

Methods

This project used a structured multi-day workshop, involving a sequence of exercises and discussion with voting, to achieve consensus among a group of leading IEQ investigators in the U.S. The workshop gathered opinions from the investigators on the following questions:

Environmental Causes

- Based on your experience as an IEQ investigator, what are the most important *environmental causes or risk factors* for building-related symptoms and discomfort complaints in U.S. office buildings?
- Why have you selected these as the most important risk factors?

Prevention Strategies

- What are your top recommended specific measures for *preventing* these health and comfort problems in office buildings (e.g., aspects of design, commissioning, operation, maintenance, or management)?
- Why do you recommend these measures?

Participating IEQ investigators considered the risk factors and prevention strategies in these categories:

- Building, initial (design, location, construction, commissioning)
- Building, ongoing (operation, maintenance, repair, replacement, housekeeping)
- Behavioral/organizational (management IEQ approach, occupant behavior)

Staff from the Indoor Environment Department at Lawrence Berkeley National Laboratory (LBNL) planned, conducted, and summarized the workshop, without contributing answers to the questions presented. After the workshop, LBNL staff, based on their familiarity with the current scientific literature, informally summarized risk factors for building-related symptoms identified in the scientific literature, compared these to risk factors identified by the IEQ investigators, and produced a summary report of the overall process.

IEQ investigators at the workshop included four in private practice and two federal government employees. These investigators provided and prioritized ideas during the workshop, and reviewed and helped revise several draft versions of the summary report.

[Table I]

Results

During the workshop, the participating IEQ investigators developed a prioritized list of building-related problems (Table 1) that, based on their collective experience, included the most important causes of building-related symptom complaints in office buildings. They defined "importance" of causes primarily by their *frequency* of causing problems requiring investigation (the additional factor of the *severity* of health problems caused, although in the original workshop concept, was

dropped). The top three problems identified were (1) excessive building moisture related to either water leaks in the building envelope or plumbing, inadequate control of humidity in the outdoor air brought in by HVAC systems, or infiltration of water vapor through the envelope; (2) inadequate amount or quality of outdoor air provided in the building, resulting from improper design, operation, or maintenance of the HVAC systems; and (3) excessive dust in the building from improperly managed renovations, inadequate housekeeping, or poor selection of interior materials.

The next environmental problem identified was (4) pollutant gases and odors in the indoor environment, resulting from outdoor air intakes improperly located near sources such as idling vehicles or traffic, improperly managed renovations, or lack of local exhaust venting for activities that generate substantial indoor pollutants. The last key environmental problem identified was (5) inadequate thermal control, resulting in thermal conditions outside an optimal range or even the broader range recommended for acceptable conditions. Causes for this problem included inadequate thermal control by the HVAC system, excessive airflow, radiant heat loss to windows, and the difficulties of using uniform thermal conditions to satisfy individual occupants with a range of thermal preferences. The final problem identified was (6) failure of building management to recognize the importance of adverse effects of IEQ and to implement preventive strategies. This problem stemmed from management decisions on design, operation, and maintenance focused on immediate costs but not on proactively maintaining good IEQ, lack of awareness of or effective responses to environmental dissatisfaction of employees, and lack of open communication on IEQ issues.

For each of these problems, the IEQ investigators then developed a set of top recommended prevention strategies (listed in Table I), related to known causes of each problem. For instance, for problems of excessive building moisture, caused by either water leaks in the building envelope, inadequate control of humidity in the outdoor air brought in by HVAC systems, or infiltration of water vapor through the envelope, they recommended water management at the building exterior, humidity control by the HVAC system, and management of water vapor transmission through the building envelope.

They then ranked the entire list of recommended strategies by relative importance in preventing building-related symptom complaints. The top ranked strategies (listed in Table II) included water management at the building exterior; ensuring provision of adequate outside air, by operating the HVAC per the original design intent, and also by providing at least the recommended minimum amount of outdoor air at each air handling unit; and maintaining indoor temperatures within a narrow range of optimal comfort around 72°F (22°C).

[Table II]

Risk factors for building-related symptoms for which support exists in the scientific literature were summarized and organized to correspond with the building-related problems identified by the investigators (Table III). For each *environmental* category of investigator-identified building-related problems, at least one scientifically documented association was available. For instance, the scientific literature has shown that symptoms are more common in office buildings with lower ventilation rates (Seppanen et al., 1999), with higher temperatures even within the

conventional comfort envelope (Jaakkola and Heinonen, 1989; Mendell et al., 2002b), and with building moisture damage (Park et al., 2002). Additional literature is available documenting such associations in buildings other than office buildings, such as residences and schools, particularly for dampness (Bornehag et al., 2001). No scientific documentation was available of symptoms caused directly by inadequate management attention to IEQ, although clearly many indoor environmental deficiencies could result from such inattention. .

[Table III]

Discussion

This project has attempted to condense and summarize valuable aspects of the empirical knowledge of IEQ investigators about the causes of building-related symptom complaints. This knowledge has not been formally summarized, although it is informally reflected in some prior guidelines for building managers; e.g., "Building Air Quality" (U.S. Environmental Protection Agency and National Institute for Occupational Safety and Health, 1991). As is often the case, the empirical knowledge of practitioners offers more guidance for choosing health-protective strategies than current science, although the efficacy of empirically based strategies often has not been confirmed.

There was remarkable agreement among the IEQ investigators, despite their experience with buildings in extremely diverse climatic regions. Perhaps most striking was that for all investigators, including one from the very moist climate in Florida and one from the relatively dry climate of New Mexico, the highest priority problem was *excessive building moisture*, and the highest priority prevention strategy was *managing water at the building exterior*. Furthermore, There was also substantial overlap between the empirically based and scientifically based lists of problems.

Because most health studies of risk factors for causing building-related symptoms do not estimate how *commonly* the risks occur or the relative *importance* of specific effects, such studies do not themselves support prioritized recommendations for prevention strategies. Separate descriptive data is available on the high frequency of some building-related risks in representative U.S. office buildings, from the U.S. Environmental Protection Agency's Building Assessment Survey and Evaluation (BASE) study (Brightman and Moss, 2000). For instance, 85% of office buildings studied had past water damage, including roof leaks in 50%; 43% had current water damage (unpublished analyses, MJM). Also, calculations with BASE data suggest that, at the time of study, 23% of BASE buildings were providing less than the minimum rate of outdoor air specified in current ventilation standards. During hot weather conditions, when ventilation systems would likely be providing their lowest rates of outdoor air ventilation, approximately 32% of the BASE buildings would provide less ventilation than provided in current standards (unpublished analyses, WJF). Available evidence thus suggests that following the recommendations presented here would improve indoor environments in a large number of office buildings in the U.S.

Limitations of study

These results were produced by a small group of IEQ investigators, primarily industrial hygienists or engineers, during a two-day meeting, through consensus based on years of

experience rather than through scientific research; however, this exercise has been useful in summarizing an important source of information on how inadequacies in buildings can adversely affect the health of occupants. The IEQ investigators in this project suggested *prevention* strategies. Although much of their work involves suggesting remediation strategies for existing problems and prevention strategies for future problems, the investigators have few opportunities for follow-up to evaluate the *efficacy* of their recommendations.

Conclusions and Implications

IEQ investigators from across the U.S. showed considerable agreement on the most important causes of building-related symptom complaints in office buildings and the key methods for preventing these problems. These recommendations are generally consistent with available research findings, and provide useful practical guidelines for those who own, manage or maintain office buildings. Critical tasks for preventing occupant symptoms in office buildings include managing moisture at building exteriors, providing adequate ventilation, and controlling indoor thermal conditions. It will be important for scientific research to better document causes and effective prevention strategies for building-related symptoms, but health-protective actions cannot and should not always wait for scientific certainty.

Acknowledgements

This work was supported by the U.S. General Services Administration, Public Buildings Service, Workplace 20.20 Project, through Interagency Agreement 1B3P02221 with the U.S. Department of Energy. We thank Allan Chen for recording and summarizing the workshop. The findings and conclusions in this article have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent agency determination or policy.

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Table I. Key problems causing building-related symptom complaints, listed in descending order of estimated importance, and recommended prevention strategies for each, based on the experience of IEQ investigators

Problem Category	Top Recommended Prevention Strategies
Excessive building moisture	• Water management of building exterior • Humidity control by HVAC • Maintain water vapor management through envelope
Inadequate amount or quality of outdoor air	• Operate per design intent (effective controls) • At least minimum rates of outdoor air (per ASHRAE) at air handling unit • Scheduled maintenance of outdoor air system
Excessive dust	• Management of renovations (containment and management of air pressure relationships) • Housekeeping • Surface and material selection
Pollutant gases and odors	• Locate outdoor air intakes away from sources • Management of renovations (containment and management of air pressure relationships) • Local exhaust venting for special uses/sources
Inadequate thermal control	• Meet ASHRAE 55 for temperature and relative humidity o Maintain 72°F ±2° (22°C ±1°) o Pay attention to radiant heat exchange, proximity to window, and window type o Limit air velocity to 25 ft/min (0.13 m/s) maximum • Control of high relative humidity (e.g., <60, 70%) • Local control of temperature
Inadequate attention by management to preventing adverse effects of the indoor environment on occupants, instead of minimizing immediate costs	• Communicate about activities that cause employee complaints, and about addressing complaints • Set up IEQ management plan (e.g., EPA/NIOSH building action plan) • Promote employee/management IEQ committees/ safety and health committees for ongoing communication

Table II. Highest priority strategies for preventing building-related symptom complaints (selected from initial priorities in Table 1), based on the experience of IEQ investigators

Problem Category	Top Recommended Prevention Strategies
Excessive Building Moisture	• Water management of building exterior
Insufficient Outdoor Air	• Operate ventilation system per design intent (requires effective controls) • Provide at least ASHRAE 62.1 minimum outdoor air ventilation rates at air handling unit
Thermal Discomfort	• Maintain indoor temperature at 72°F ±2° (22°C ±1°)

Table III. Likely causes of building-related symptom complaints: priority problems identified by IEQ investigators compared to related problems identified in the scientific literature[1, 2]

Building-related problems causing symptom complaints, identified by IEQ investigators	Building-related risk factors associated with symptoms in office buildings, identified in the scientific literature
• Excessive building moisture	Moisture and microbial growth in occupied space, within building envelope (Park et al., 2004), or in HVAC system (Mendell et al., 2003) Presence of air-conditioning or humidification systems, especially with wet or dirty surfaces (Mendell et al., 2003; Seppanen and Fisk, 2002)
• Inadequate amount or quality of outdoor air	Inadequate outdoor air ventilation rate (<10 l/s-person, or possibly <20-25 l/s-person) (Seppanen et al., 1999)
• Excessive dust	Airborne and surface particles or dust indoors (Chao et al., 2003; Pan et al., 2000; Skulberg et al., 2004; Wålinder et al., 1999) Fungi in floor dust (Chao et al., 2003; Gyntelberg et al., 1994)
• Pollutant gases and odors	Carbon monoxide from attached vehicle garages (Kreiss, 1989) Emissions from carpets, new computers (Bakó-Biró et al., 2004; Norbäck and Torgen, 1989; Wargocki et al., 2002)
• Inadequate thermal control	High temperatures even within recommended comfort range (Jaakkola and Heinonen, 1989; Mendell et al., 2002b)
• Inadequate attention by management to preventing adverse effects of the indoor environment on occupants	None identified

[1] excluding radon, asbestos, lead, tobacco smoke, and *Legionella* bacteria

[2] identified as risks by either definite, persuasive, or suggestive scientific evidence, based on an informal literature review by coauthor 1; not ordered by strength of evidence or estimated importance